

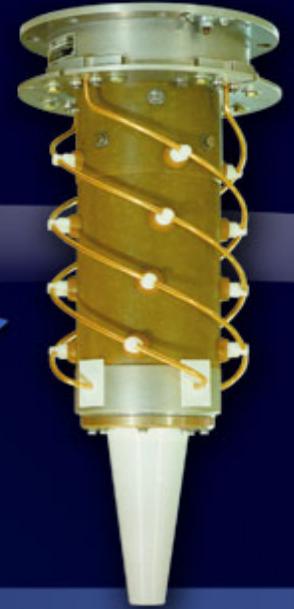
International Doris Service

DORIS System Overview

F. G. Lemoine

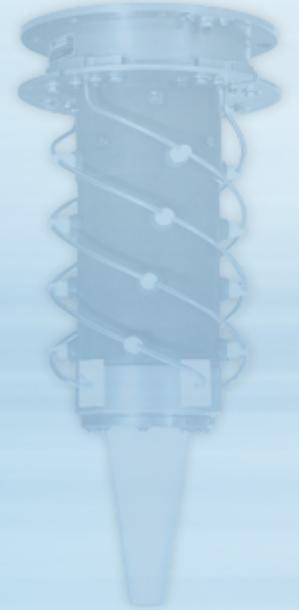
Space Geodesy Group, Code 698 @ NASA GSFC

June 6, 2012



Outline

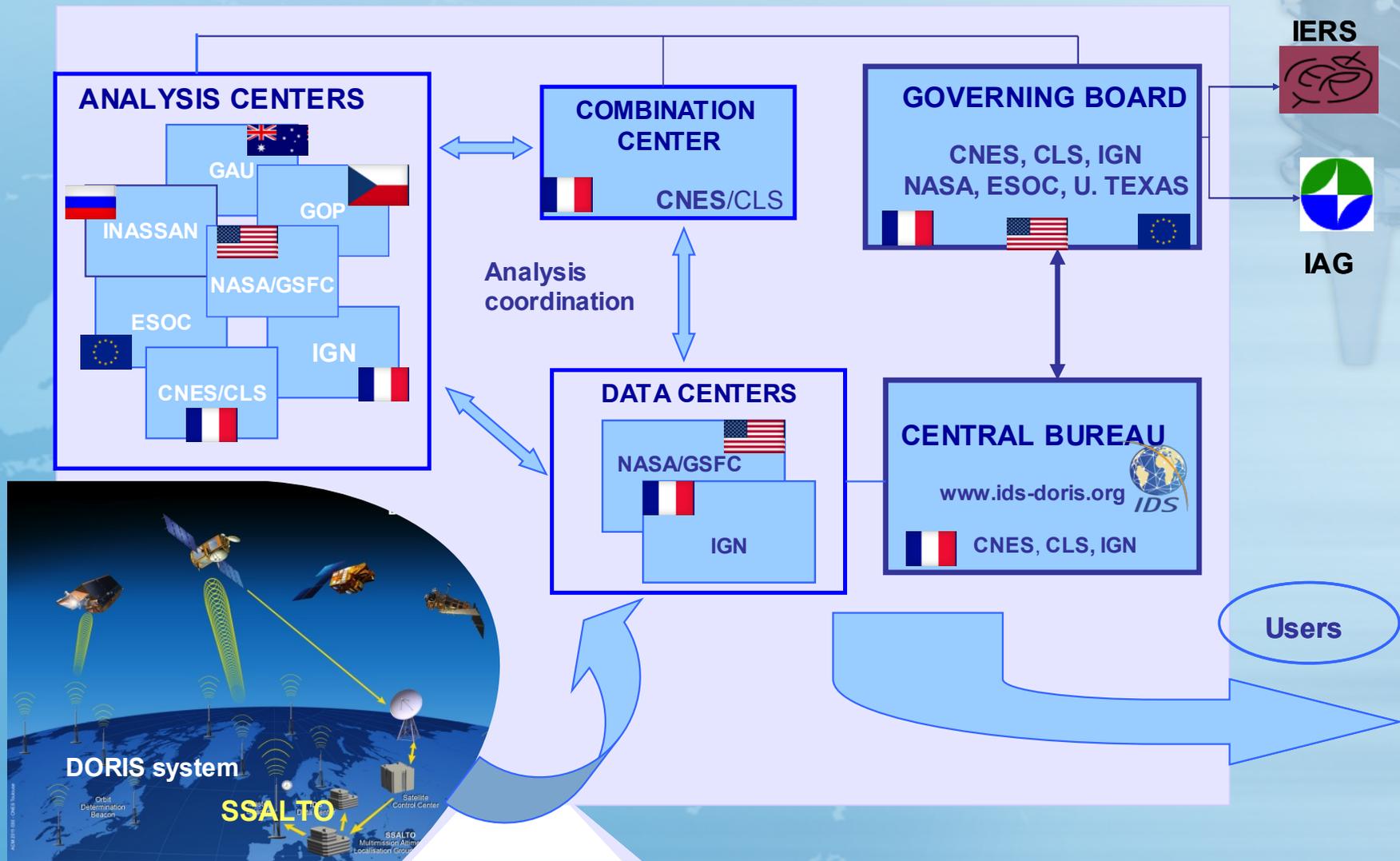
1. **DORIS System Elements**
 - **Ground network & coverage**
 - **Satellite constellation**
 - **Collocations**
2. **IDS Organization & Data Analysis**
3. **DORIS data applications**
4. **Status: DORIS stations in the US**
5. **Summary**



What is DORIS?

- I. **DORIS = *Doppler & Radiopositioning Integrated by Satellite.***
- II. **~55 Dual-Frequency Doppler Beacons (2.036 Ghz & 401.25 Mhz), distributed around the world.**
- III. **Developed by the *CNES (Centre National d'Etudes Spatiales) & IGN (Institut Géographique National), France.***
- IV. **The network was developed to support Precision Orbit Determination (POD) for LEO satellites, such as the SPOT remote sensing satellites & altimeter satellites such as the *NASA/CNES* mission, TOPEX/Poseidon.**
- V. **DORIS data (*along with SLR, GPS, VLBI*) contribute to the determination of the terrestrial reference frame (*e.g. station coordinates, geocenter, Earth orientation*) & to vertical height rate determination at tide gauge sites.**
- VI. **The oldest sites in the network have been occupied since 1988-1990 (*DORIS data are routinely available since 1992 - the launch of TOPEX/Poseidon*).**

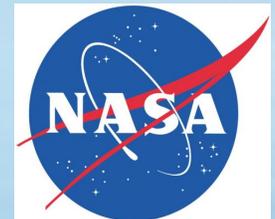
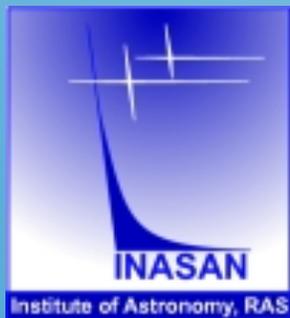
DORIS System Schematic



International DORIS Service --- Status (1)

Components

- 2 Data Centers: (IGN; NASA CDDIS @ NASA GSFC).
- 7 Analysis Centers: European Space Agency (*Germany*), Geoscience Australia, NASA/GSFC, Geodetic Observatory Pecny (*Czech Republic*), Institute of Astronomy (*Russia*), IGN (*France*), CNES/CLS (*France*).
- 1 Combination Center (*Toulouse, France*)



International DORIS Service --- Status (2)

Current Activities

- Analysis Centers regularly deliver products to Data Centers (*weekly station coordinate solutions + EOP; Geocenter; Orbits*).
- Combination Center produces IDS solution – like the other geodetic techniques – but quarterly.
- Preparing for Submission of new Combined Solution to next ITRF (ITRF2013).
- Updates to Models (*Satellite Force models, and Measurement models*).

Past & Future Events

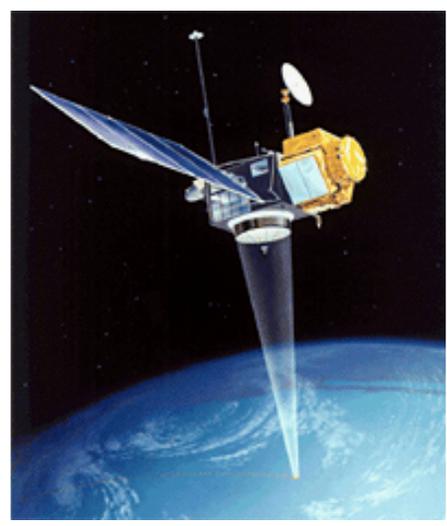
- Analysis Working Group meeting, Prague CZ, 5/31-6/1, 2012).
- IDS Workshop, Venice Italy (Sept 26-27, 2012).
- Special session Fall AGU (December 2012)

DORIS Colocations (detail)

- ~55 stations (49 Third generation beacons): Homogenous global coverage.
- Improved long term stability of the antenna reference point.
- Co-location with other IERS techniques: **GPS, 37; SLR, 9; VLBI, 8.**
- Co-location with tide gauges (sea level monitoring): **23 stations.**
- Co-location with altimeter calibration site: **1 station (Gavdos, Greece).**
- Stations with the longest occupations and the most technique colocations are the most valuable:
 - ✦ **Greenbelt (4)** , ¶ **Hartebeesthoek (4)** , ¶ **Yarragadee(4)** ,
 - ✦ **Kokee Park/Kauai (3)** , ¶ **Arequipa (3)** , ¶ **Tahiti (3)** , **Ny**
Alesund (3), Metsahovi (3) ...
 - ✦ *NASA geodetic site (US).*
 - ¶ *NASA affiliated site.*

(DORIS-VLBI @ Hartebeeshoek = ~2200m; DORIS-VLBI @ Kokee = ~360 m; DORIS-VLBI @ GGAO = ~230m)

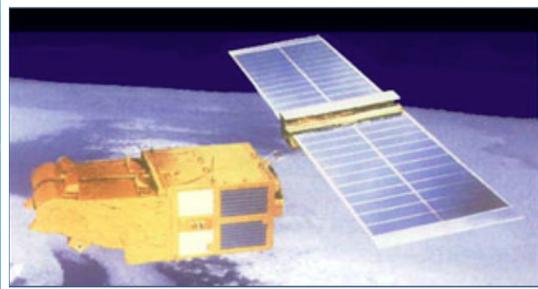
DORIS Constellation Status - Past Missions



**TOPEX/Poseidon:
1992 - 2004**

NASA/CNES

Ocean radar altimeter

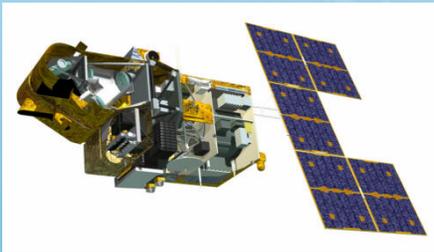


**SPOT2: 1990 - 2009
SPOT3: 1993 - 1995**

CNES

Image Remote Sensing

DORIS Constellation Status - Current Missions



CNES



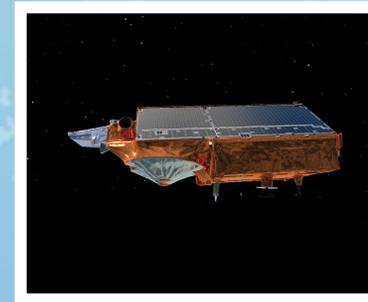
ESA

SPOT4: 1998 - 2012
SPOT5: 2002 - 2015

Envisat: 2002 - 2013+



Jason1: 2002 - 2013
Jason2: 2008 - 2015-2016++



ESA

Cryosat2: 2010 - 2013++

NASA+CNES+NOAA+EUMETSAT

DORIS Constellation Status - Future Missions



CNES/ISRO

SARAL/Altika: 2012 - 2016+



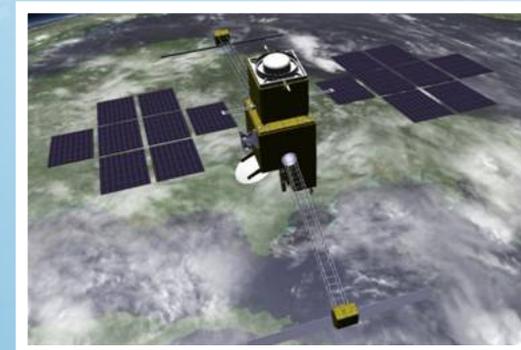
ESA

Sentinel 3A: 2013 - 2018+
Sentinel 3B: 2015 - 2020+



Jason3: 2014 - 2019+
JasonCS: 2018 ----->

NASA+NOAA+CNES+EUMETSAT



SWOT: 2020 ----->

NASA/CNES

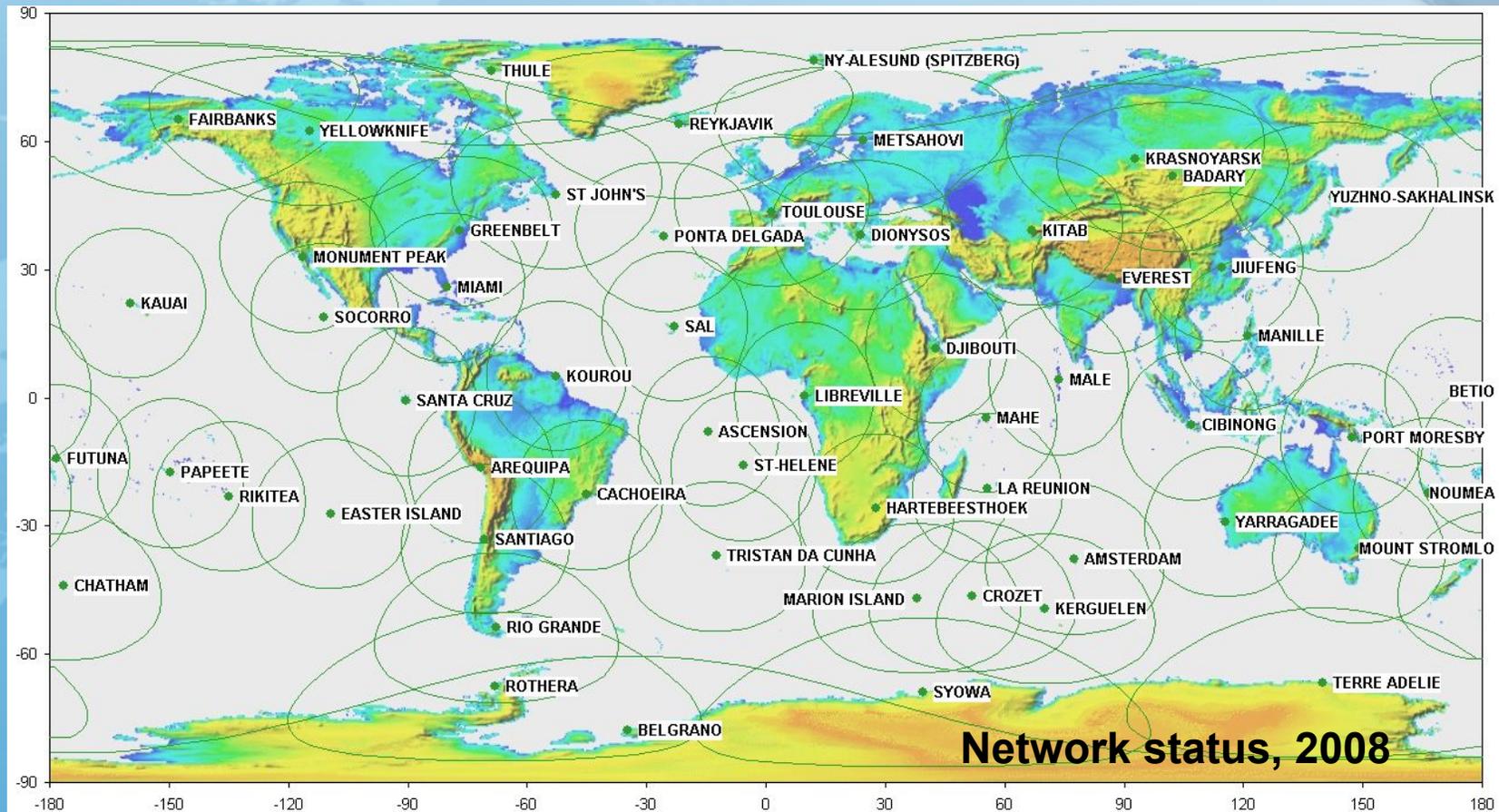
DORIS Satellite Receivers - Evolution



DORIS Satellite receivers have evolved considerably since the first receivers were launched on SPOT2 and TOPEX/Poseidon in 1990 and 1992. In terms of performance the biggest change has come in the number of channels available (how many beacons can be tracked at one time): The quantity of data available is increased enormously benefitting near-real time and ITRF applications.

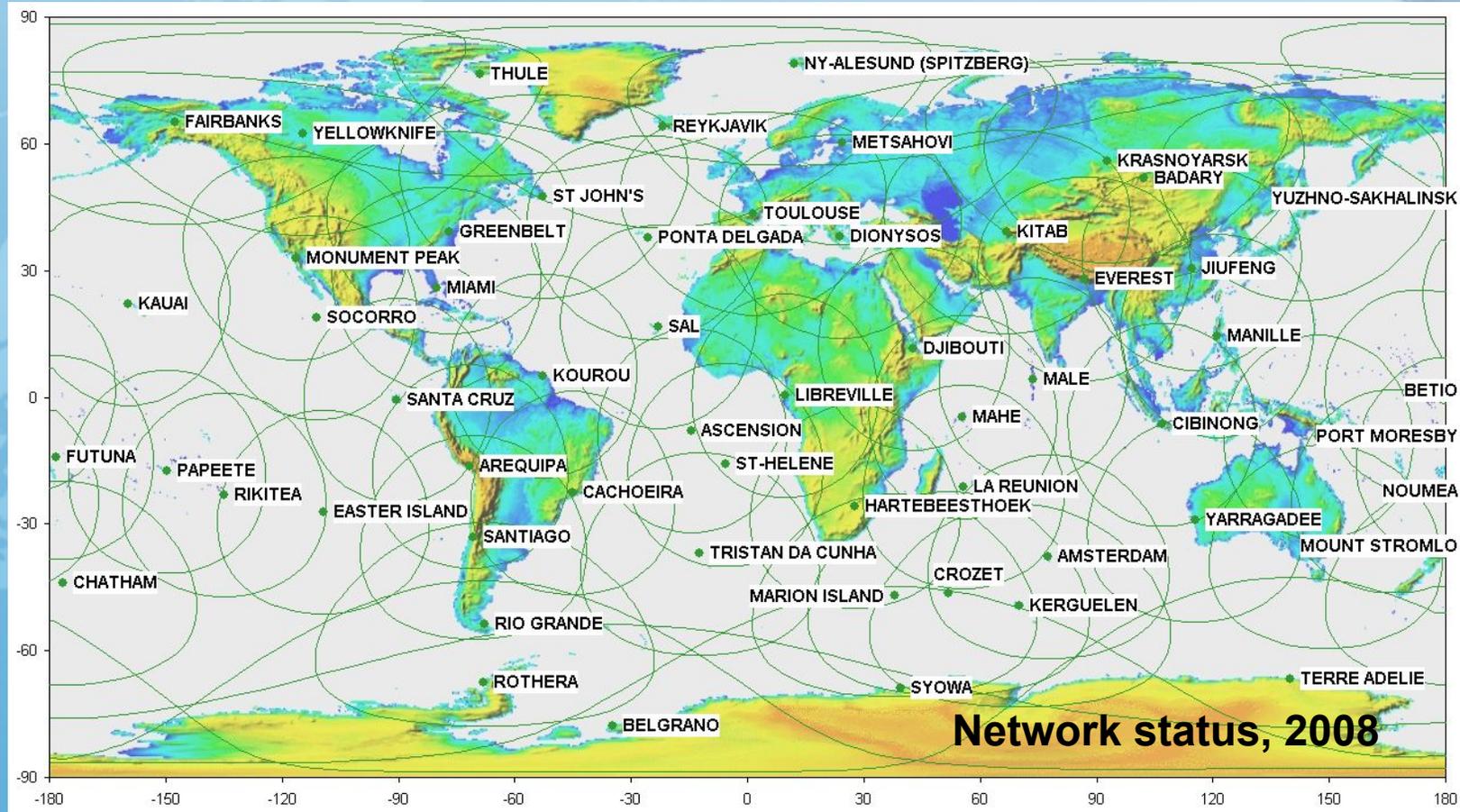
1 channel	SPOT2, TOPEX/Poseidon, SPOT4
2 channels	SPOT5, Envisat, Jason1
7 channels	Jason2, Cryosat2

Visibility Masks for DORIS Stations for ENVISAT altitude (~800 km) & 12° Elevation



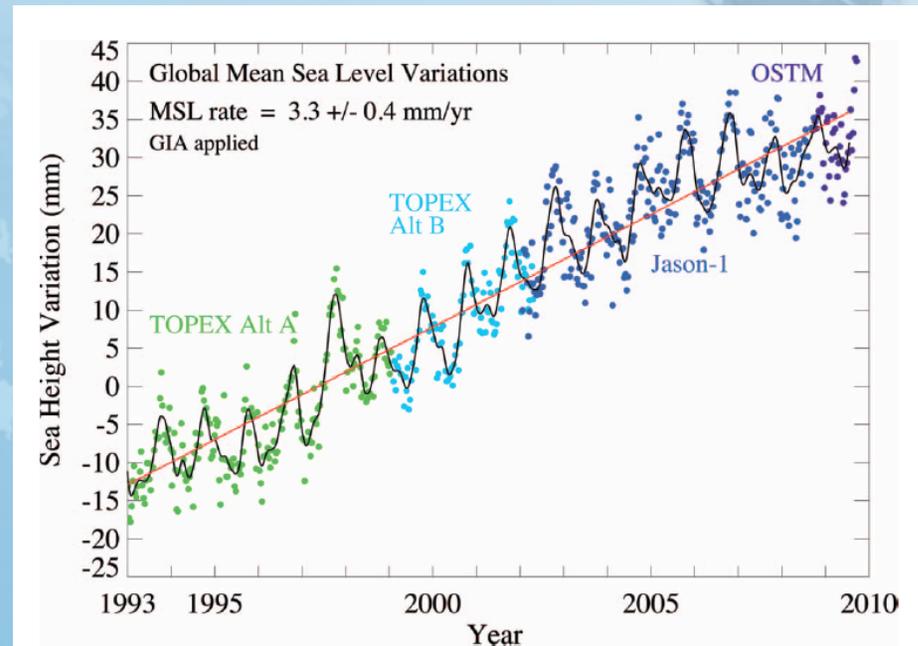
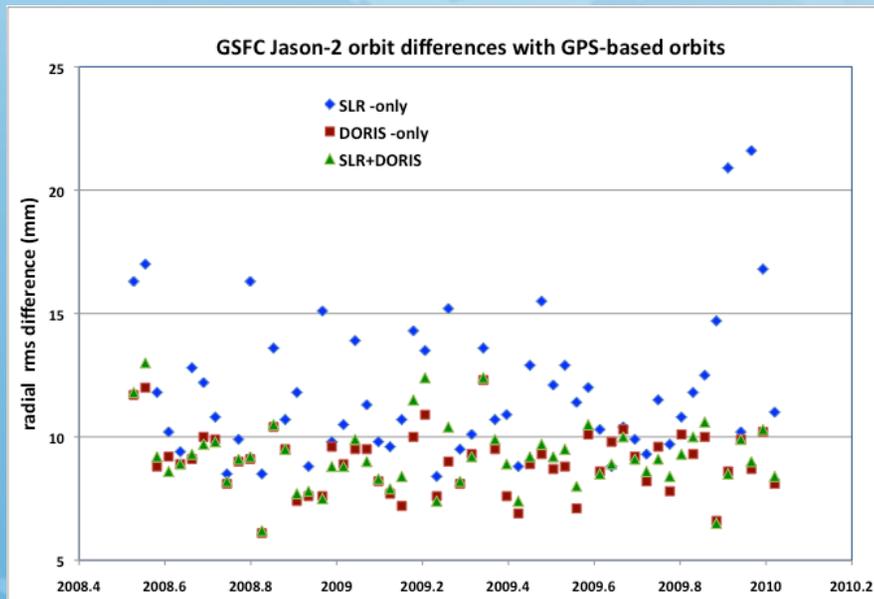
**Since 2008, Monument Peak & Fairbanks were decommissioned;
New station was installed at Cold Bay (Alaska).**

Visibility Masks for DORIS Stations for Jason altitude (~1335 km) & 12° Elevation



Since 2008, Monument Peak & Fairbanks were decommissioned;
New station was installed at Cold Bay (Alaska).

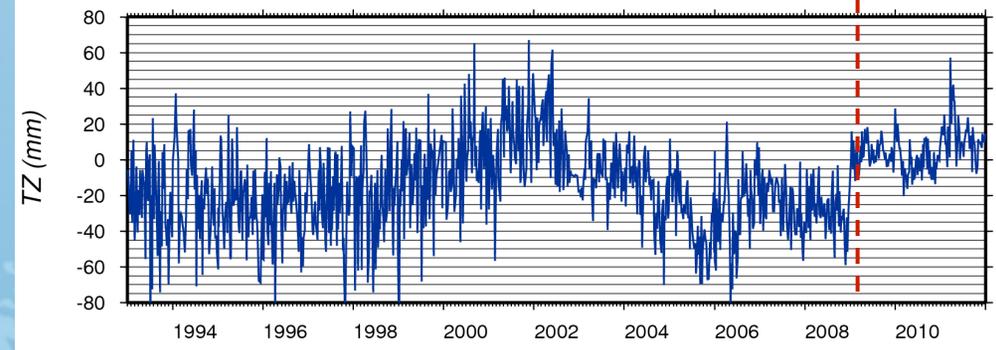
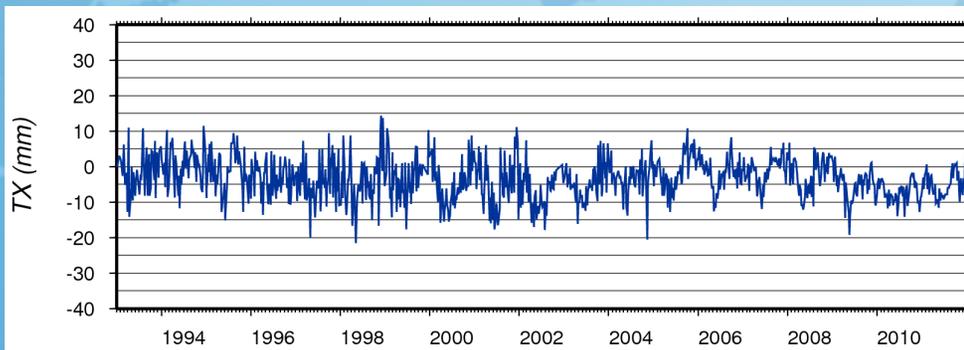
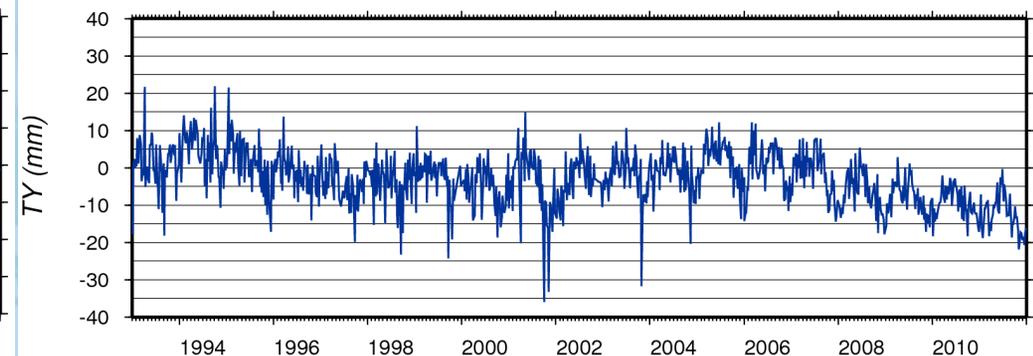
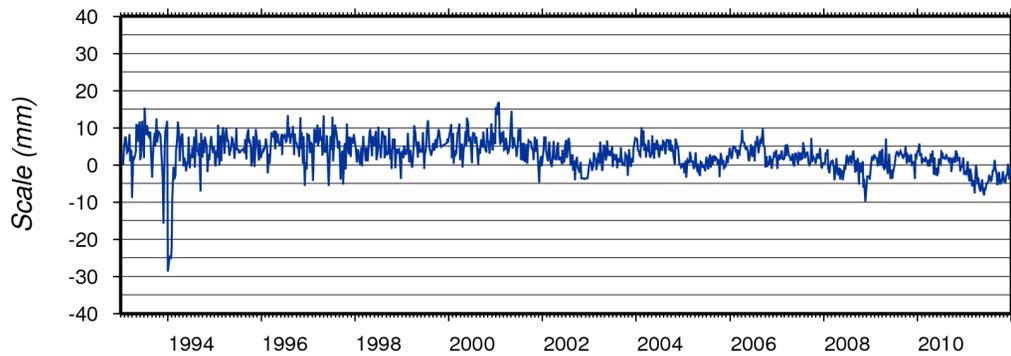
Application (example): Precise Orbit Determination



SLR + DORIS and DORIS-only orbits are superior to SLR-only orbits (above example for Jason-2, but the same is true for Jason-1 and TOPEX).

The determination of change in global mean sea level in the altimetry era (after 1993) is done with **SLR+DORIS** orbits in a consistent reference frame. (Beckley et al., *Marine Geodesy*, 2010; Lemoine et al., *Adv. Space Res.*, 2010)

Application (example): Terrestrial Reference Frame

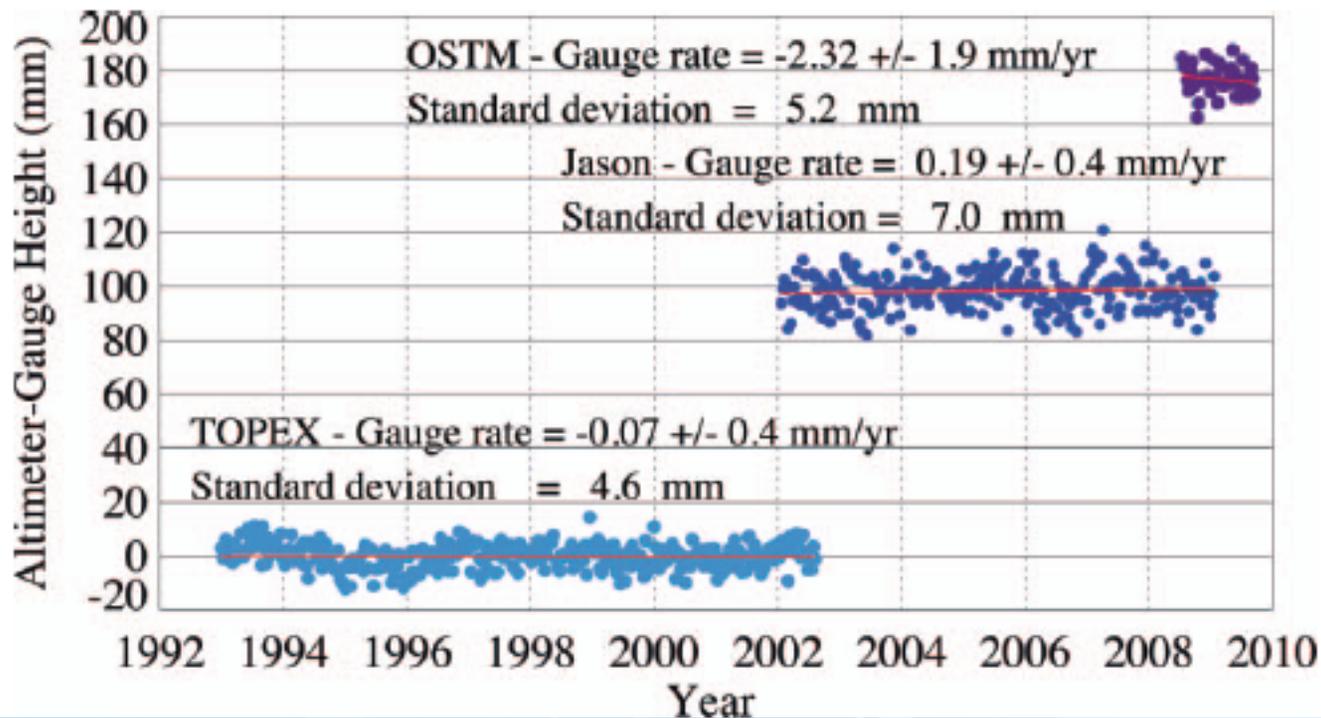


ITRF2008 Scale & Origin variations from DORIS (*extended to 2011*)

DORIS System Overview, F. G. Lemoine, Space Geodesy Group @ NASA GSFC, June 7, 2012



Application (example): Altimeter tide-gauge calibration



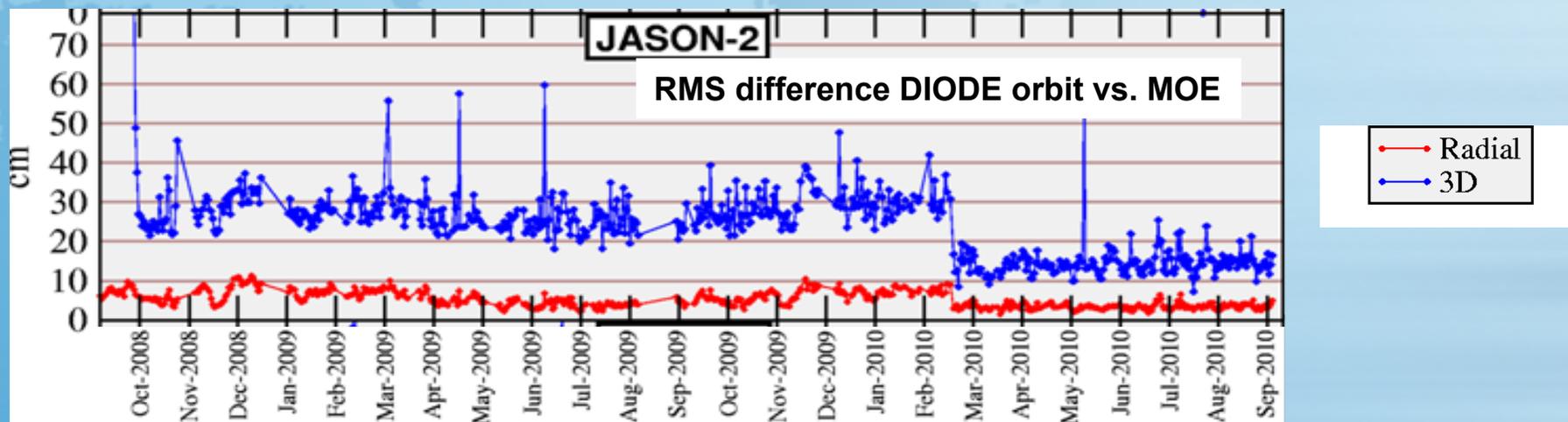
DORIS enters into the determination of mean sea level in two ways:

1. (Directly) The orbit determination for the altimeter satellites (**TOPEX**, **Jason1**, **Jason2**)
2. (Indirectly) Determination of the vertical rates at some of the tide gauge sites.

Monitoring the global average of the differences between sea level between altimetry data and the tide gauges allows us to monitor the performance of the altimeter system and guard against any instrumental drifts.

Application (example): Near-real time Orbit Determination on Jason-2

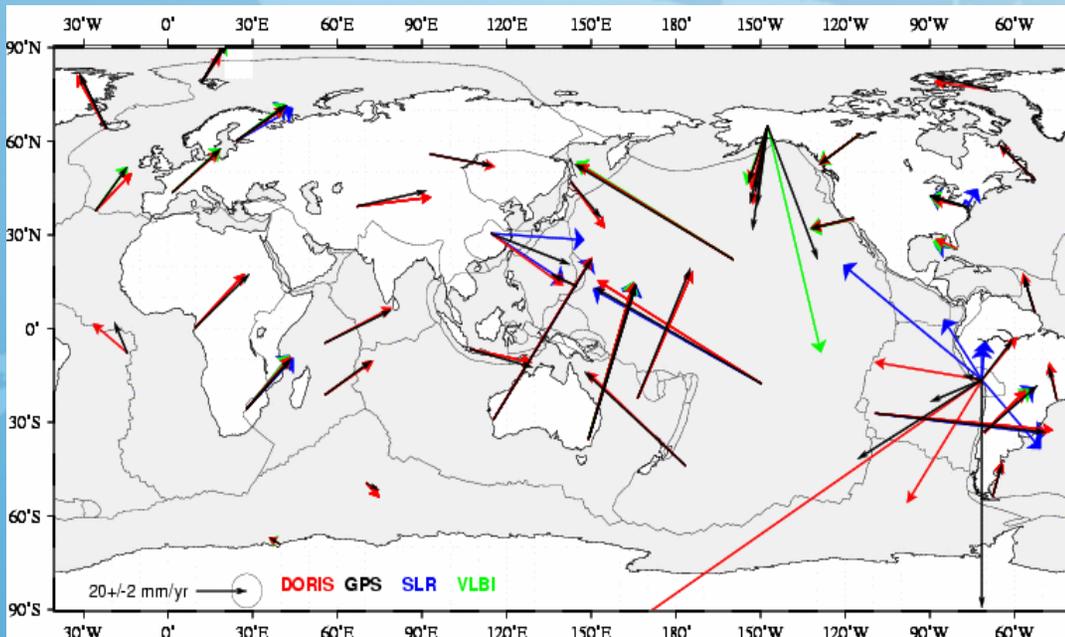
The DORIS/DIODE receiver on-board the DORIS satellites is used for real-time navigation and generation of near-real-time data products. The RMS radial agreement on Jason-2 between the near-real time orbits (distributed within several hrs after data download) is below 5 cm after a flight software upgrade in March 2010. This allows the Jason-2 altimetry data to be ingested into near-real time ocean models.



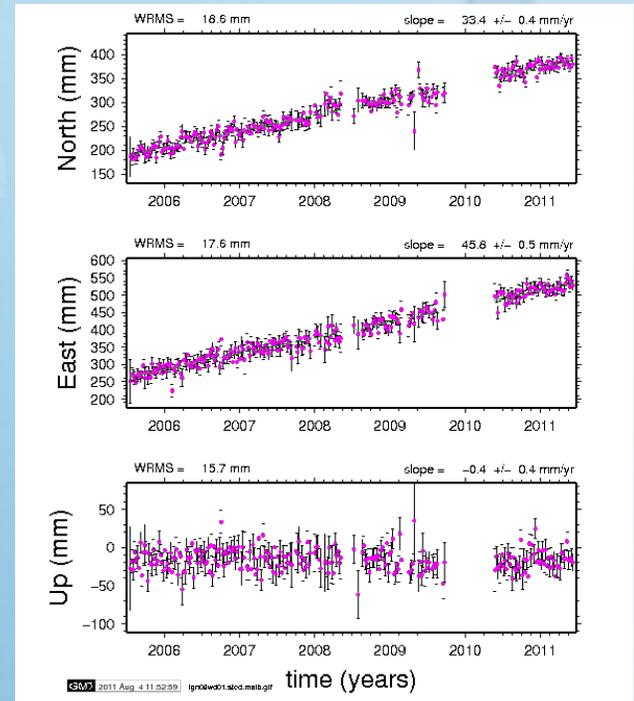
(from Jayles et al., 2010 OSTST meeting)

Application (example) Station motion & TRF

ITRF2005 Horizontal velocity comparisons:
DORIS vs other techniques

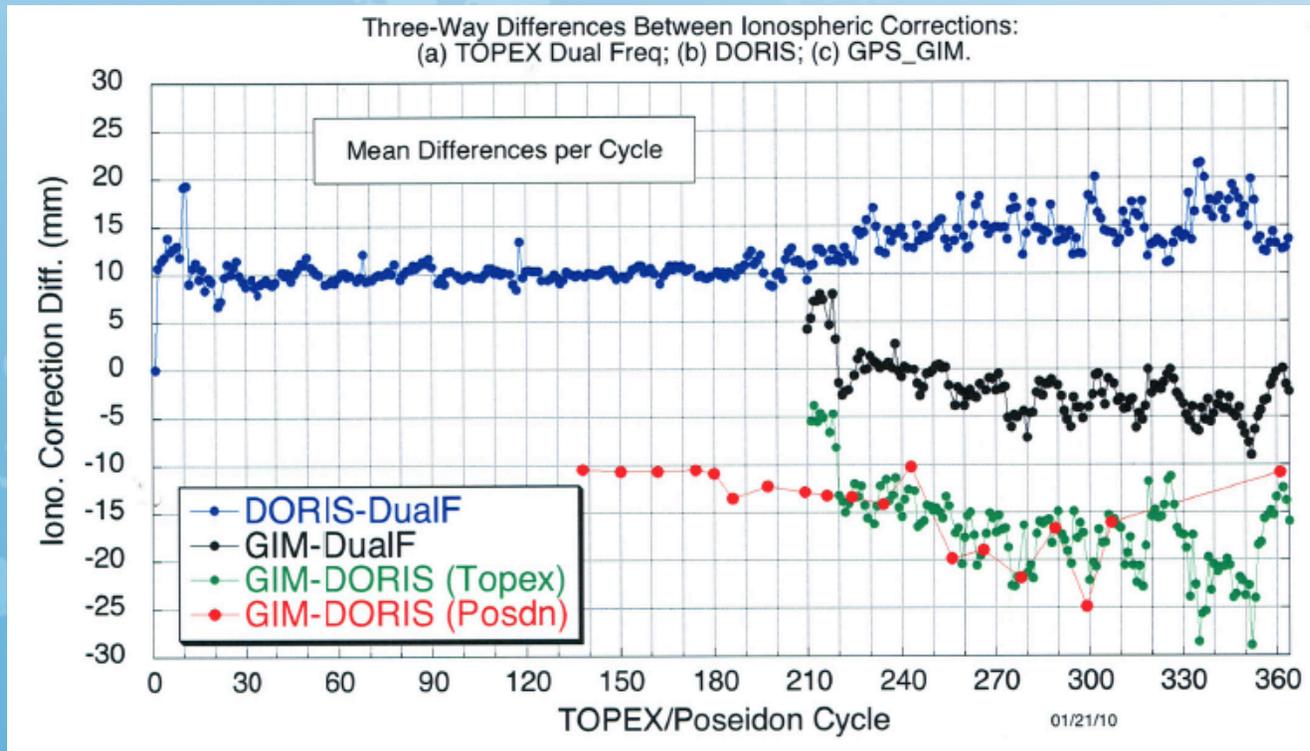


IGN09wd01 solution for Malé
(Maldives) -- Indian Ocean
island with tide gauge.



Application (example)

Ionosphere correction calibration for Altimetry



*From Simon Holmes
& Brian Beckley,
NASA GSFC, Jan.
2010.*

Three-way Ionosphere Differences for TOPEX/Poseidon: Altimeter vs. DORIS; GPS/GIM vs. Altimeter; GPS/GIM vs. DORIS. While a bias can be calibrated and accounted for, any drift in the ionosphere range correction would map directly into the long-term analysis of the satellite altimeter data. DORIS provides one of the tools to monitor altimeter satellite performance.

US DORIS stations

Site	Location	Lat (deg)	East Long. (deg)	Ht (m) (¥)	Comments
Greenbelt	GGAO (1)	39.020070	283.172103	21.003	Colocat. with SLR, GPS, VLBI.
Miami	Virginia Key (2)	25.732783	279.83689 4	-11.557	Colocation with GPS & Tide gauge .
Kauai	Kokee Park (3)	22.123056	200.33456 9	1167.53	Colocation with GPS & VLBI.
Cold Bay	Aleutian Islands SW of Kodiak Island, Alaska .	55.190420	197.29323 7	50.6 5	Replacement for Fairbanks. Operational since Nov. 2010.
Goldstone	Near DSS13. 60 miles from Barstow, CA (4)	35.248367	243.20810 6	1041	Location of DORIS site until 2004; Likely replacement for Monument Peak. Site survey by FGL & BJH May 2010 & by CNES Oct 2011 .
Fairbanks	NOAA/NESDIS (5)	64.972311	212.48242 5	340.163	Decommissioned 2010.
Monument Peak	Mt Laguna, California (6)	32.891854	243.57763 5	1843.91 0	Decommissioned.

(¥) Height above reference ellipsoid. $A_e = 6378136.46$ m. $1/f = 298.256$.

(1) Location: Goddard Geophysical and Astronomical Observatory (GGAO).

(2) Host: Rosentiel School of the Marine Academy of Science, University of Miami.

(3) Location: Kokee Park Geophysical Observatory, Kauai, Hawaii.

(4) Location: Near DSS13/Goldstone.

(5) Location: NOAA/NESDIS site. DORIS Station decommissioned, Summer 2010.

(6) Location: on premises of NASA SLR station .

Cold Bay, Alaska



- Operational on facilities of US Coast Guard since November 2010.
- Site negotiations facilitated by NOAA (Giovanni Sella).
- NGS/NOAA CORS GPS site.

Koike Park (Kauai)

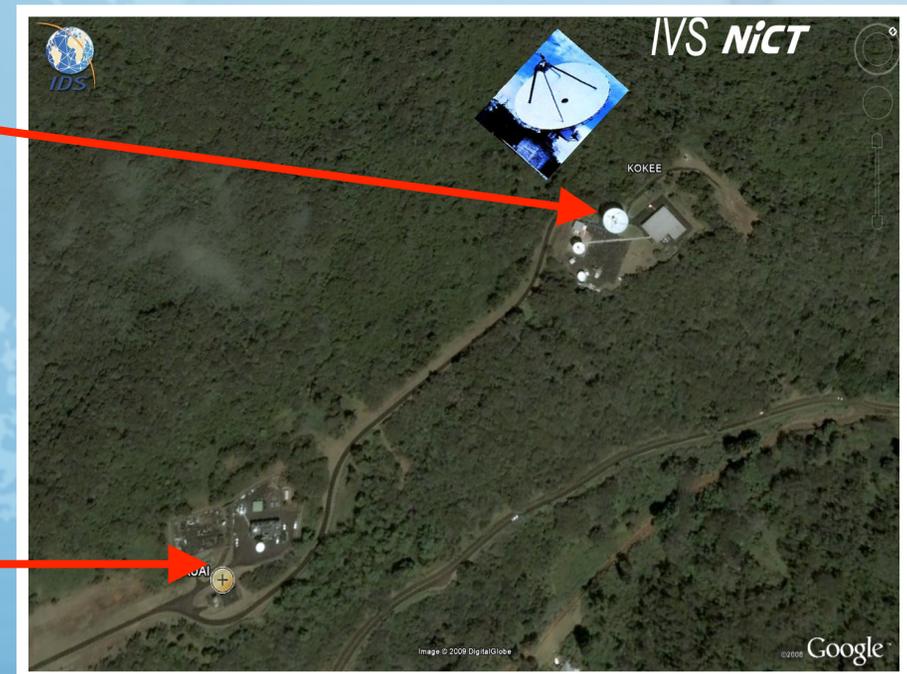


- Operational since Sept. 26, 1990 on grounds of Koike Park Geophysical Observatory (north of Waimea Canyon State Park, western Kauai).
- Colocated with VLBI & GPS.



VLBI

DORIS



Virginia Key (Miami)



- Operational since Feb. 10, 2005 on the grounds of Rosentiel School of Marine and Atmospheric Science, University of Miami.
- Colocated with 2 IGS stations (*AOML*, ~231 m; *MIA3*, ~294 m, & *GLOSS tide gauge WOCE 9023*, ~183 m).
- DORIS Station replaces old DORIS site at Richmond, Florida (*occupied 1993 - 2005*).

Greenbelt

(Goddard Geophysical and Astronomical Observatory)

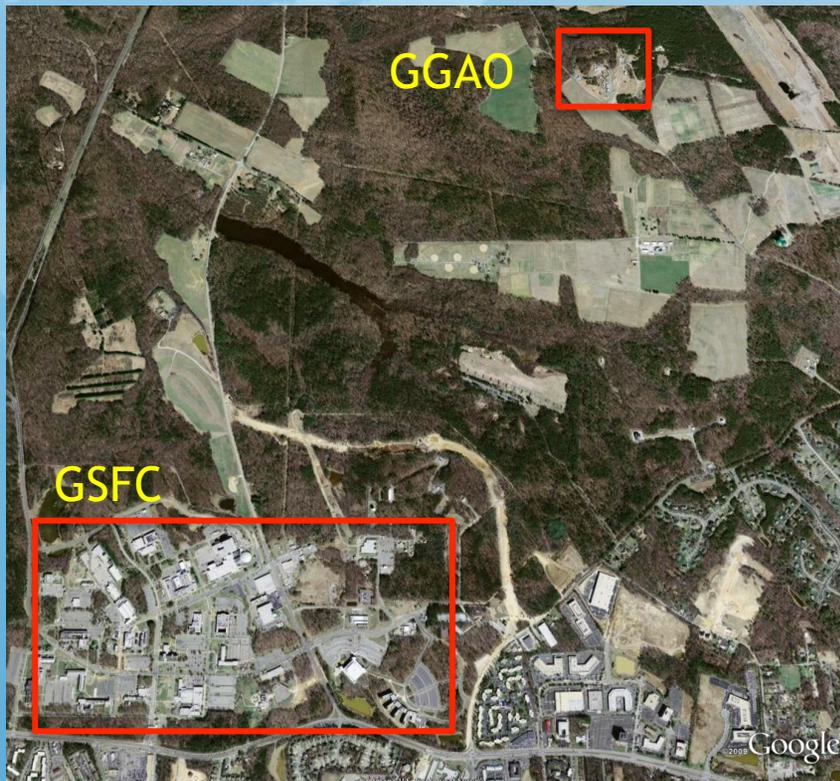


- DORIS @ GGAO has been operational since June 29, 2000.
- Colocated with SLR, GNSS, & VLBI.
- The GGAO site has been used for satellite laser ranging since the 1960's and serves as host for NASA's next generation geodetic station.
- It currently hosts operational satellite laser ranging (SLR) with MOBLAS7 & NGSLR.
- The next generation VLBI radio telescope (VLBI2010) was installed at the GGAO in late 2010 and is under development.

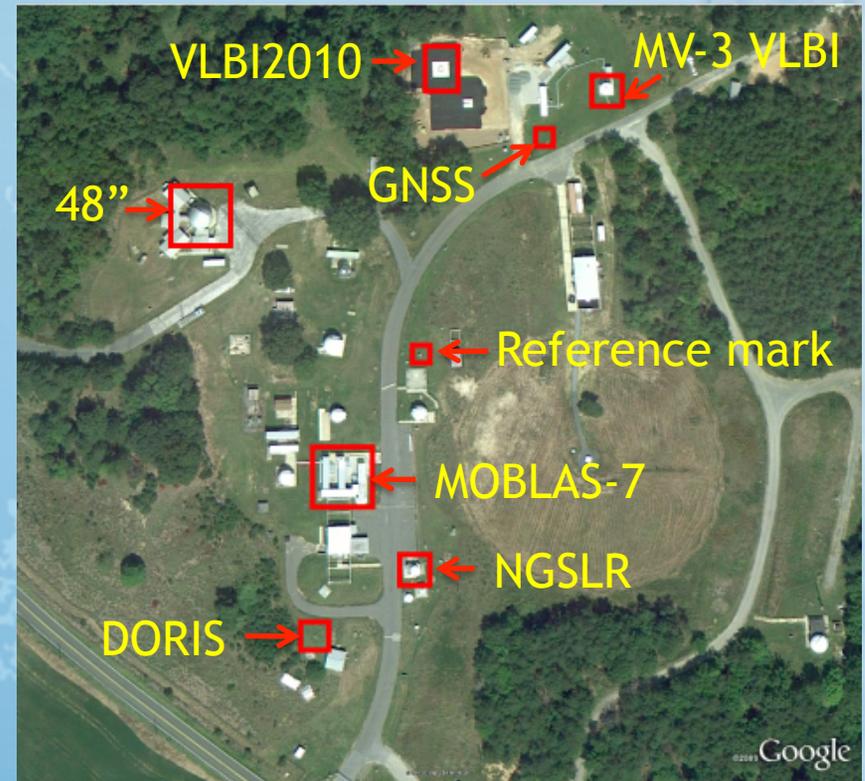
Greenbelt

(Goddard Geophysical and Astronomical Observatory)

Local Area Map



GGAO



Goldstone (near DSS13)



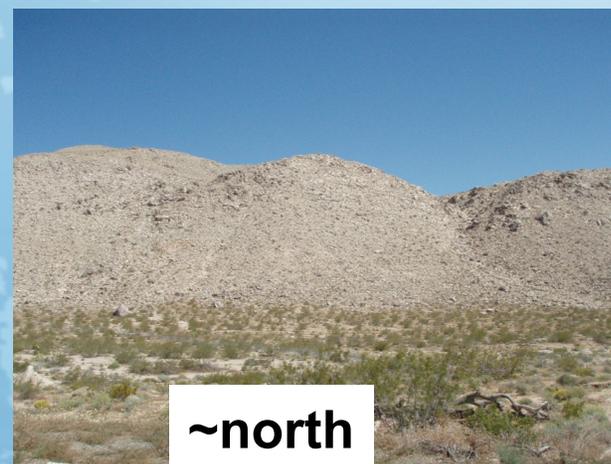
site overview



~southwest



**Concrete pad with old mobile VLBI marker
(south of old Goldstone DORIS site)**



~north



<http://ids-doris.org>



Australian Government
Geoscience Australia

INSTITUTE OF ASTRONOMY
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Newcastle
University